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Interpretation methods and practices

Quality Committee training session
New Orleans, LA - November 1999

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Agenda

- Overview of the STEP interpretation process
- Analysis principles
- STEP Integrated Resources - overview of the data architecture
- Analysis example/exercise
- Mapping table syntax - introduction (with examples)
- EXPRESS usage for AIMs - introduction (with examples)
- Reusable interpretations (templates)
- Conclusions and discussion

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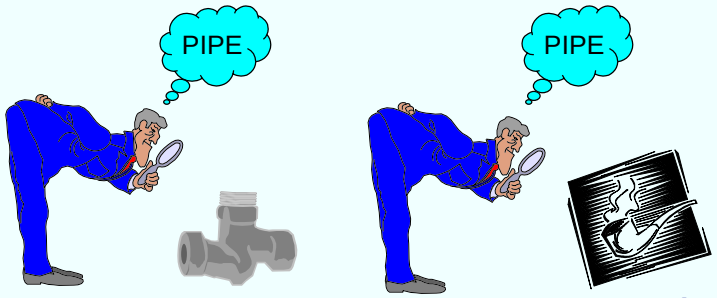
Semantics and context

- Information has utility when:
  - the meaning of the information (the semantics) …
  - … and the background knowledge necessary to draw inferences (the context)
- are known



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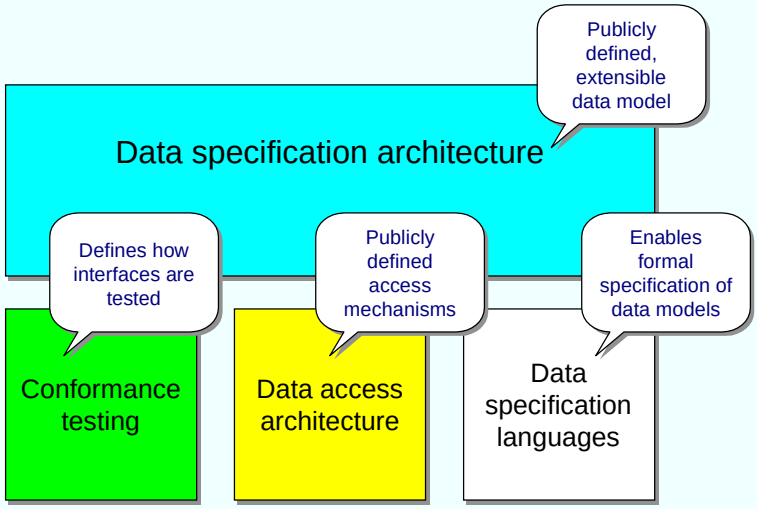
The STEP architecture



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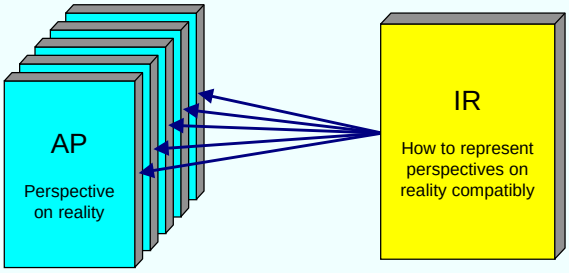
Principal elements of the STEP product data architecture



Acknowledgement: W. F. Danner (NIST)

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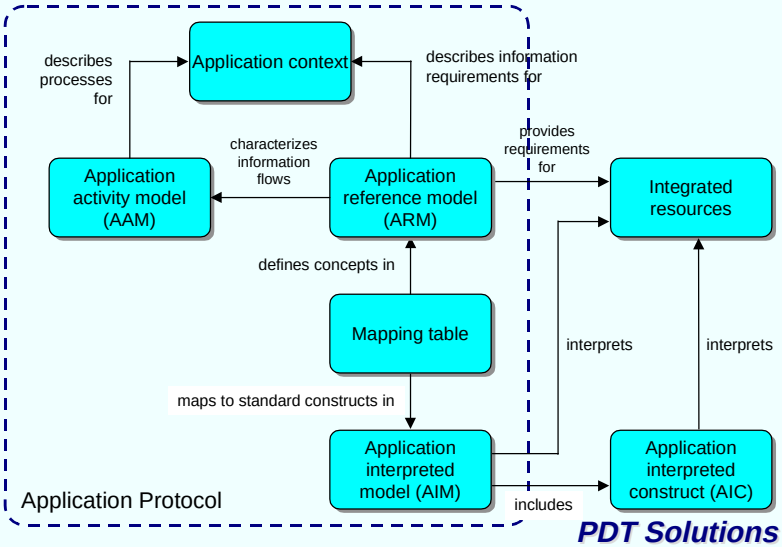
Data specification architecture



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A key distinction ...

- Application Protocols (APs) specify standardized industry application semantics
- The standard data specifications contained within APs are based on common Integrated Resources (IRs)
- IR: standardized definition of product data
  - ⇨ The IRs are a single integrated model
- AP: standardized application of product data
  - ⇨ APs are consistent solutions to different industry needs

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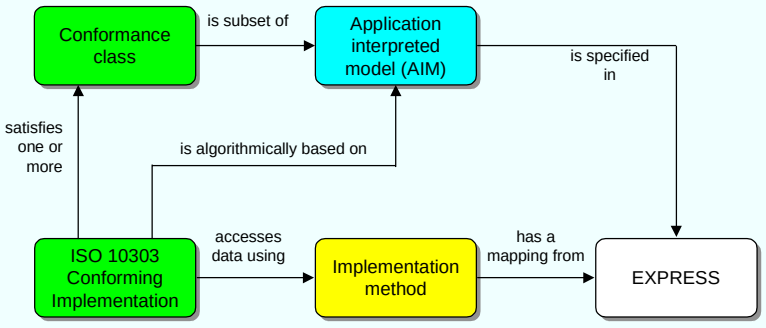
Data access architecture / EXPRESS



- Integrated resources and Application interpreted constructs are also specified in EXPRESS

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Integration vs Interpretation

- INTEGRATION
  - Development and maintenance of the Integrated Resources
  - Goal: availability of common, generic resource constructs that support the requirements of many application areas
  - Undertaken by WG12
- INTERPRETATION
  - Satisfying the requirements of an individual application protocol, using the constructs in the integrated resources
  - Goal: data specifications (AIMs) that are consistent across multiple Aps
  - Undertaken by individual project teams, using methods/guidelines published by the Quality Committee

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Benefits

- INTEGRATION:
  - Consistent basis for all STEP APs - different industry viewpoints within a single standard
  - Minimal redundancy across APs - "describe the same thing the same way"
  - Enables reuse of interface/translator code for multiple AP implementations
- INTERPRETATION
  - Application of a single analysis method to produce the normative data specification of all STEP APs
  - Designed to enable interoperability across multiple APs (where requirements are shared) through common solutions

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Overview of the interpretation process

- Preparation for interpretation
- Interpretation workshop(s)
- Documentation
- Post-workshop activities

Feedback/ Iteration

- Several workshops may be required to complete the task
  - ⇨ depends on scope and complexity of the AP's requirements
- Resolution of CD and DIS ballot comments may require further interpretation work

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Key documents

- AP Guidelines
- AIM development guidelines
- Mapping table guidelines
- Procedures for application interpretation
- Supplementary directives

- Integrated resources
- Other APs with overlap in scope
- AICs

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Workshop participation and role(s)

- AP project leader/workshop facilitator
- Domain expert(s)
  - explain/clarify requirements of the AP domain
- AP project team members
  - conduct UOF and ARM walkthroughs
  - take workshop minutes (➠ interpretation report)
  - record mappings (➠ mapping table)
  - record usages and specializations of the IRs (➠ AIM short form)
- Interpretation expert(s)
  - analyse requirements of the AP domain
  - support AP team in mapping requirements to STEP IRs

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Workshop preparation

- AP project leader/team members …
  - ensure that requirements are agreed and fully documented
  - initial familiarization with interpretation process
- Interpretation expert(s) …
  - preliminary review of AP requirements – UOFs, ARM
  - prepare training materials, as required
- Workshop logistics
  - AP document
  - ARM diagrams, supporting examples
  - partially completed mapping table

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Interpretation workshop(s)

- Training
- Walkthrough of AP requirements
- Develop interpretation strategy
- Analysis of AP requirements
- Mapping to STEP IRs

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Workshop procedures

- Work will be **very intensive** - make best use of time without causing physical/mental breakdown!
- Note-takers set the pace!
- Suggestions:
  - ⇨ note-takers to complete the day's notes as 'homework'
  - ⇨ start each day with one-hour review of previous day's results
- If requirements/ARM issues arise, note them for offline resolution, and move on …

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Documentation

- Meeting notes, interpretation report
  - record rationale for every interpretation decision
- Mapping table
  - used to record agreed mappings from ARM to AIM
  - also used as a “checklist” for completion of the interpretation task
- AIM short form notes
  - IR entity types that will be used in the AIM
  - specializations (subtypes) of imported IR entity types
  - completion of management resource templates
  - requirements for global rules
  - requirements for modifications to imported entity type definitions

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Post-workshop activities

- Completion of all workshop documentation
- Completion of AIM short form interface (USE FROM) statements
- Consideration of independent instantiability
- Validation of the EXPRESS
- AIM long form generation
- AIM short names generation
- Creation of AIM EXPRESS-G
- Quality checks

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Analysis principles

- Application interpretation
- Development of the standard data specification (AIM) that fulfills the requirements of the AP
- Analysis of information requirements:
  - relationships to underlying STEP concepts
  - overlaps with other APs
  - voids in the STEP Integrated Resources
- Mapping of each ARM entity, attribute & relationship
- Creation of AIM and Mapping Table
- Identification and use of AICs

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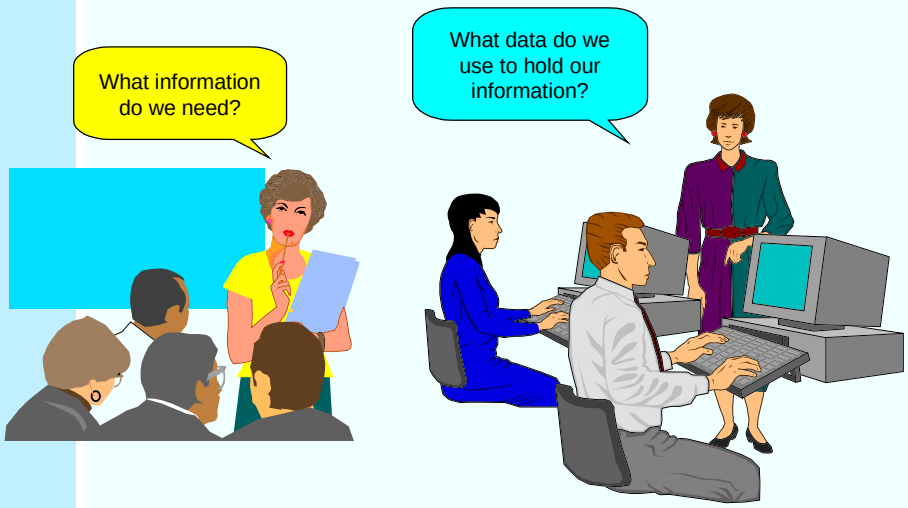
Information and data



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Applying the STEP methodology

- Identify the processes that use or operate on product data
  - design
  - manufacturing
  - installation
  - …
- Each process uses a subset of the total data about the part
  - discipline or application “views”
  - application protocols
  - conformance classes

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Applying the STEP methodology

- Interpret the STEP integrated resources to meet the data requirements
  - map to the concepts of the STEP Integrated Resources
  - selection of constructs
  - specification of constraints

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Integrated resources and Application interpreted models

- IRs are ***generic***
- Each AIM is a view that identifies ***specific usages*** of the IRs
- AIM includes:
  - imported IR constructs
    - IR definitions may be refined for the context of the AP
  - specialized (subtyped) imported IR constructs
    - local (WHERE) rules may be specified
    - DERIVED attributes may be specified
  - completion of product data management resources
  - global rules
  - TYPE, FUNCTION definitions as required

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STEP integrated resources – overview of the data architecture

- Framework for product data modelling ("Generic Product Data Model")
- Based on classification of the types of data that describe products:
  - application context
  - product identification
  - product definition
  - product property definition
  - product property representation
  - product property presentation

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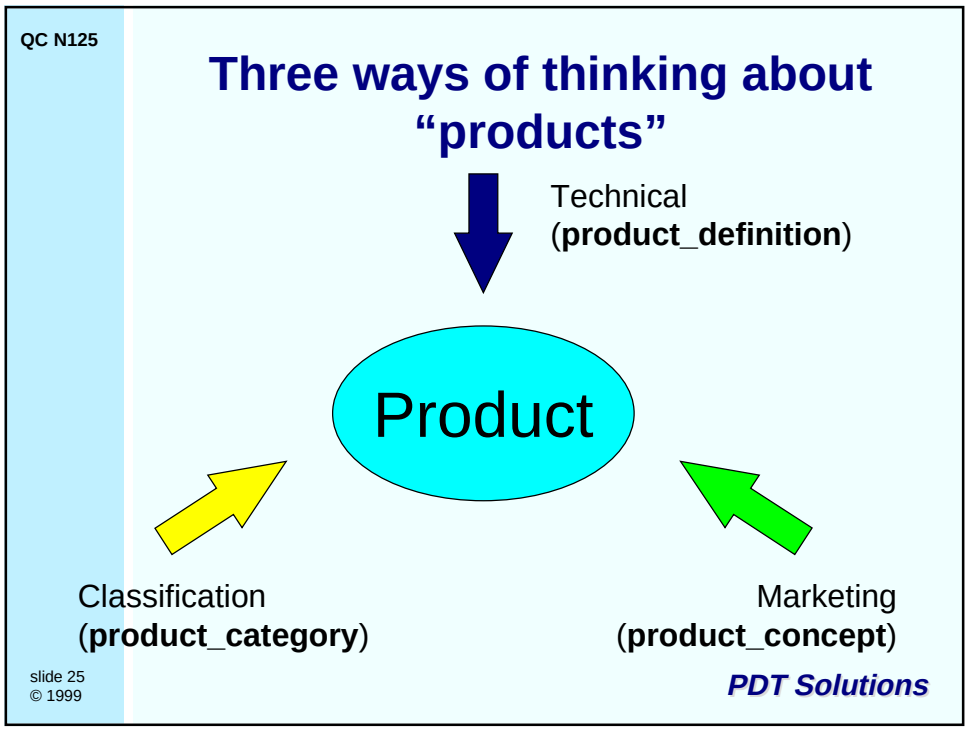
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Three ways of thinking about "products"
Technical
(product_definition)
Product
Classification
(product_category)
Marketing
(product_concept)
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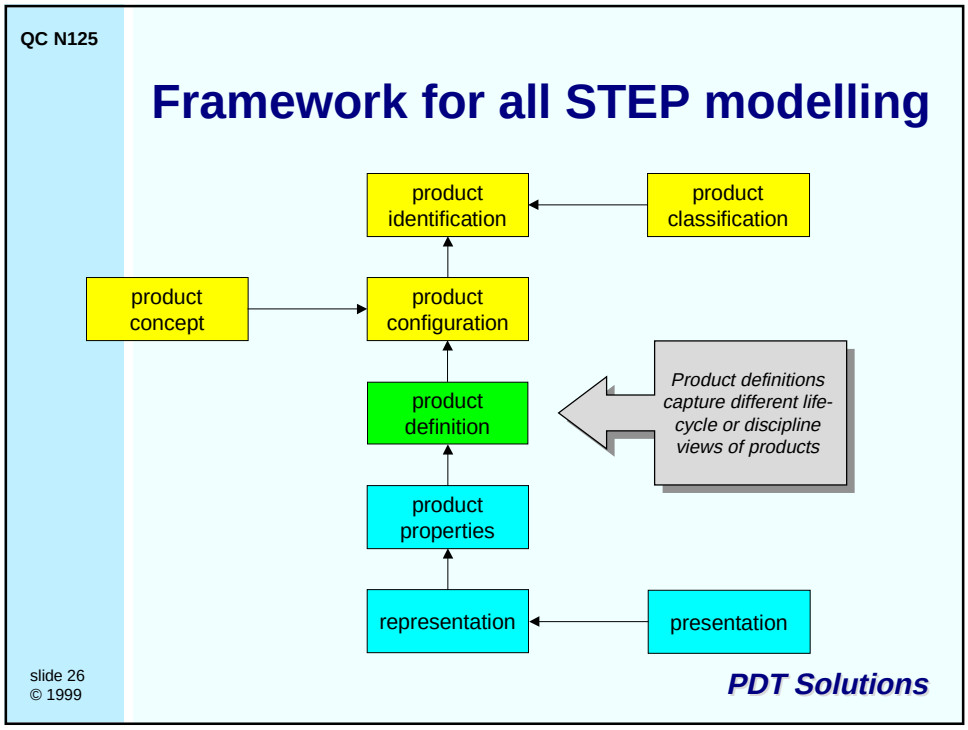
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Framework for all STEP modelling
product identification
product classification
product concept
product configuration
product definition
Product definitions capture different life-cycle or discipline views of products
product properties
representation
presentation
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STEP Integrated Resources Overview of the data architecture

- The following slides depict the major information units at the core of the STEP Integrated Resources
- Notes:
  - some detail is omitted
  - based on the IS (1994) editions *(for the proposed second editions, detail of the EXPRESS may have changed, but the underlying principles are the same)*
- For details see:
  - *Procedures for application interpretation* (clause 5.2) … which is based on …
  - *Information units and views in STEP* … available from http://www.pdtsolutions.co.uk/standard/papers/infounit/infounit.htm

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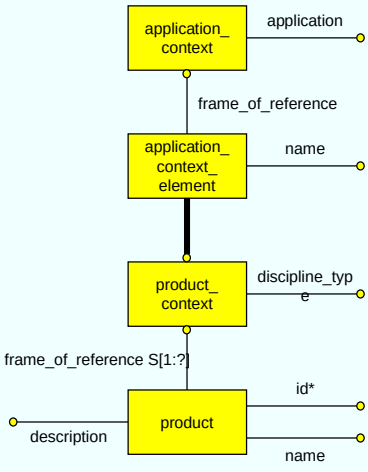
The *product* information unit



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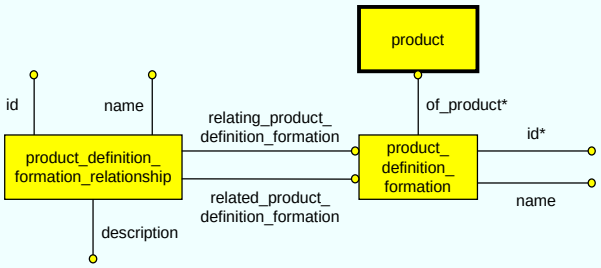
The *product configuration* information unit



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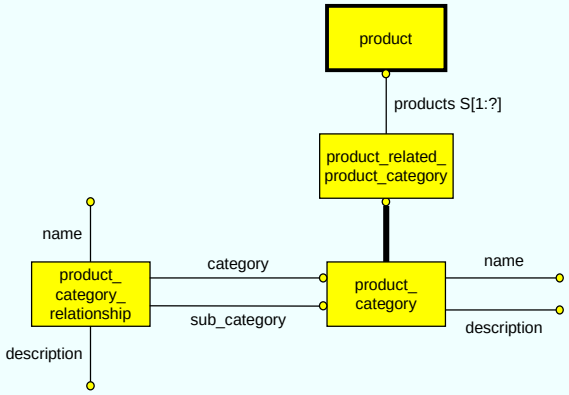
The *product category* information unit



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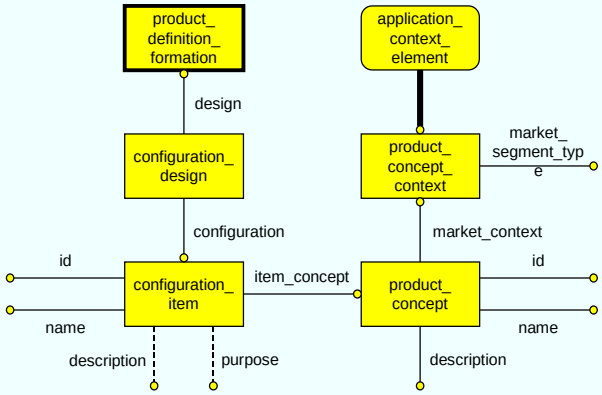
The *product concept* information unit



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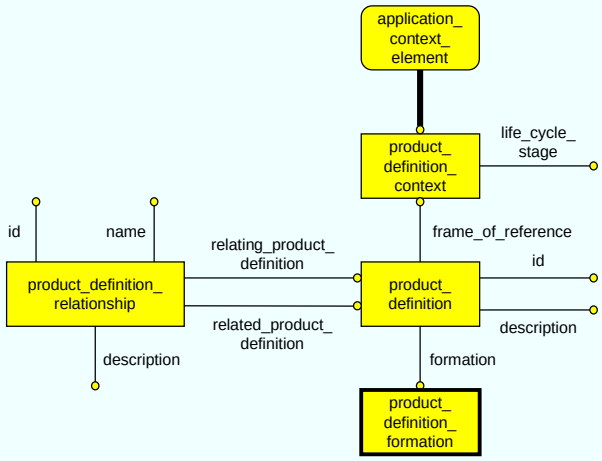
The *product definition* information unit



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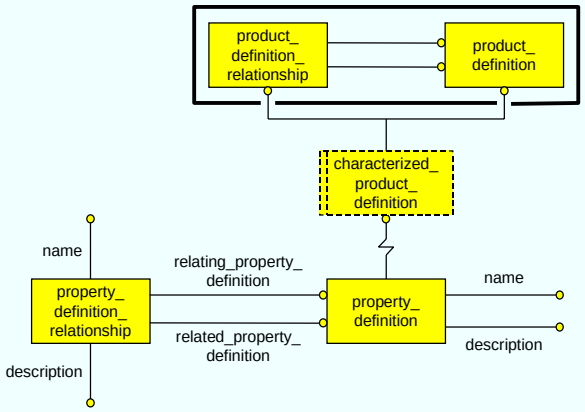
The *property definition* information unit



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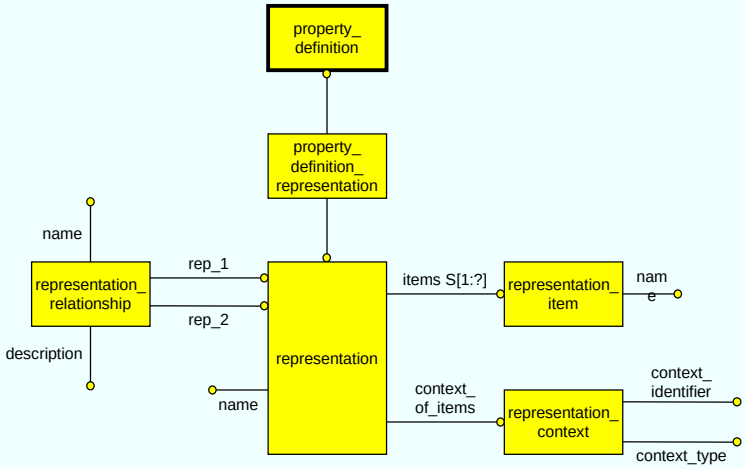
The *representation* information unit



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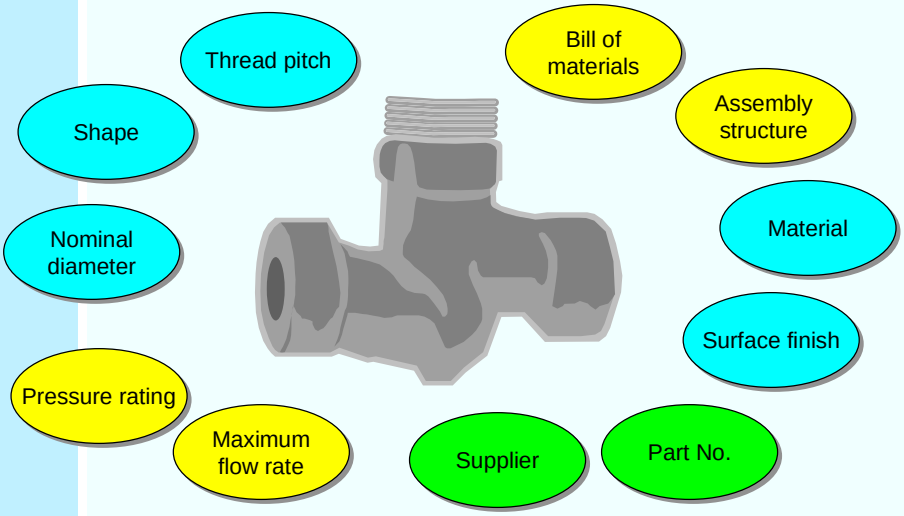
Analysis example/exercise



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Worked example

- "Mini Application Protocol"
- Specification of basic design information for plastic piping components

- **Phase 1: analysis**
- Phase 2: mapping

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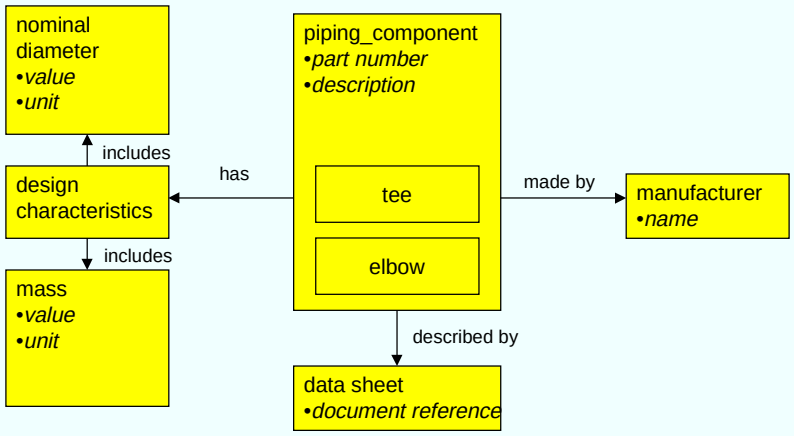
Requirements (ARM)



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Exercise: analysis phase

- Discuss and agree correspondences between ARM concepts and STEP IR concepts

piping component	
data sheet	
manufacturer	
design characteristics	
nominal diameter	
mass	

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Worked example - mapping phase

- "Mini Application Protocol"
- Specification of basic design information for plastic piping components

- Phase 1: analysis
- **Phase 2: mapping**

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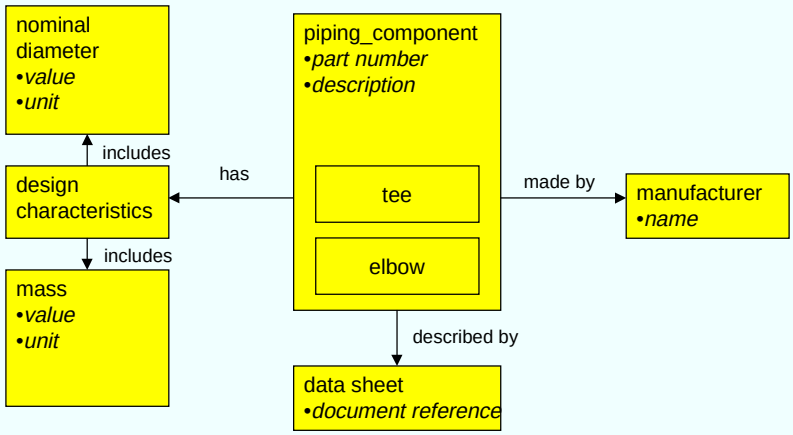
Requirements (ARM)



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Mapping methods

- Use of resource entity types
- Subtyping
- Completion of management resources
- Global rules
- "Mapping rules"
  - ⇨ population constraints stated in the mapping table
- Refined definitions

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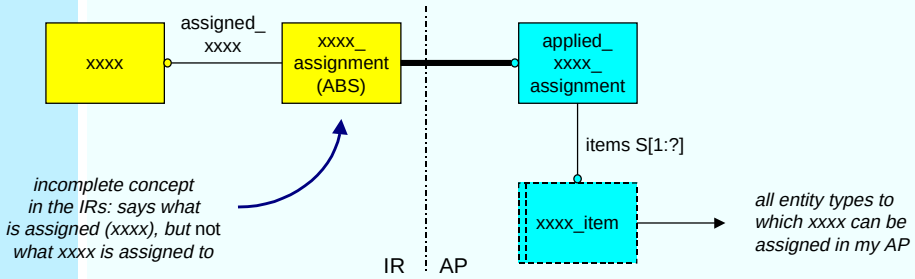
Completion of management resources

- The only circumstance in which an attribute/relationship is "added" to an IR entity data type
  - ⇨ not really addition … the IR concept is incomplete (ABS)
    … the "additional" attribute makes the concept complete



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Reference path syntax

- ←, → references, is referenced by
- ⇒, ⇐ supertype of, subtype of
- = member of SELECT type, ENUMERATION type, or specific attribute value (literal)
- ( ) option
- [ ] multiple sections (two or more)
- { } mapping rule
- < > multiple mapping
- | | mapping to supertype only
- #m case m (of n to be considered)
- aggregate[i] any member of aggregation

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EXPRESS usage for AIMs

- AIM-defined subtypes
  - ⇨ DERIVEd attributes – not widely used
  - ⇨ local (WHERE) rules
  - ⇨ concept completion (management resources template)
  - ⇨ note that the use of redeclared attributes for specification of constraints is deprecated in AIM development
- Global RULEs
- Interfacing, instantiability and SUBTYPE/SELECT type pruning
- Details are provided in the AIM Development Guidelines

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AIM-defined SUBTYPEs – DERIVEd attributes

- Practice employed if there is a requirement for application-specific attribute names in the AIM
- Alternative is to refine the *definition* of the attribute
- Example:

```
ENTITY product_definition_composition
SUBTYPE OF (product_definition_relationship);
DERIVE
  whole : product_definition :=
          SELF\product_definition_relationship.
          relating_product_definition;
  part  : product_definition :=
          SELF\product_definition_relationship.
          related_product_definition;
END_ENTITY;
```

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AIM-defined SUBTYPEs – constraints

- Specification of constraints that apply to different usages of an IR construct – have to be *localized* in SUBTYPEs
- Example:
  - ⇨ Requirement R1 – **product_definition** is always a component in an assembly
  - ⇨ Requirement R2 – **product_definition** is never a component in an assembly
- We must create two SUBTYPEs of **product_definition** that:
  - ⇨ partition the population of the generic entity type
  - ⇨ specify the constraints that apply to each partition

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Entity behaviour constraints: example

```
ENTITY component_in_assembly
SUBTYPE OF (product_definition);
WHERE
  WR1: SIZEOF (USEDIN (SELF,
       'AIM_SCHEMA.PRODUCT_DEFINITION_RELATIONSHIP.' +
       'RELATED_PRODUCT_DEFINITION')) >= 1;
END_ENTITY;

ENTITY discrete_component
SUBTYPE OF (product_definition);
WHERE
  WR1: SIZEOF (USEDIN (SELF,
       'AIM_SCHEMA.PRODUCT_DEFINITION_RELATIONSHIP.' +
       'RELATED_PRODUCT_DEFINITION')) = 0;
END_ENTITY;
```

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Referential integrity constraints

- May be requirements to specify different – and often conflicting – constraints depending on usage in the reference path of another (generic) entity type
- SUBTYPEs of the *referencing* entity type are created to establish a context for the constraint
- Often used in constraining usages of various **representation_item**s for different types of **representation**

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Example

- In representation 'A' all measure_representation_item instances must be length_measure_with_unit
- In representation 'B' all measure_representation_item instances must be plane_angle_measure_with_unit
- Constraints are established in two subtypes of **representation**

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Example

```
ENTITY representation_a
SUBTYPE OF (representation);
WHERE
  WR1: SIZEOF (QUERY (mri <*
       QUERY (item <* SELF\representation.items |
       ('AIM_SCHEMA.MEASURE_REPRESENTATION_ITEM'
       IN TYPEOF (item))) |
       NOT (('AIM_SCHEMA.LENGTH_MEASURE_WITH_UNIT'
       IN TYPEOF (mri))
       ))) = 0;
END_ENTITY;
```

- Note use of nested `QUERY`s, and:
  `SIZEOF (QUERY ( <population> | NOT ( <condition> ))) = 0`
  to state that `<condition>` is true for all members of `<population>`

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Concept completion and assignment

- Requirement: products and product_definitions have an associated date
-
```
TYPE dated_item = SELECT
  (product,
   product_definition);
END_TYPE;

ENTITY applied_date_assignment
SUBTYPE OF (date_assignment);
  items: SET [1:?] OF dated_item;
END_ENTITY;
```

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Global RULEs

- Enforce instantiation as SUBTYPE(s)
- Cardinality constraints
- Referential integrity constraints
- Attribute domain constraint

- Described, with templates, in the AIM Development Guidelines

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Schema/schema interfacing

- Purpose:
  - to allow constructs defined within one schema to be used in another schema
- There are two interfacing specifications:
  - **USE** - data types only (entity and user defined)
  - **REFERENCE** - all constructs except RULE

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USE

- EXPRESS: Allows entities and types in one schema to to be used in another as if declared within the second schema
- This is important when we consider the independent existence of data types
  - Entities and types USEd into a schema have an independent existence in any implementation of that schema, i.e. they may be instantiated directly
- STEP: Copies entity and/or type definitions from one schema to another
  - Used in selecting Integrated Resource constructs and importing their definitions into an Application Interpreted Model (AIM)

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REFERENCE

- EXPRESS: allows constructs in one schema to be visible to another for use with NO independent existence available for those items referenced
- STEP: used to add schemas to Integrated Resources (extension)

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Implicit references

- A foreign declaration will probably refer to objects which are not obviously visible to the schema making the interface.
- Those objects therefore are implicitly referenced in the interfacing schema.
- For each implicit reference resolved in this manner there may be other objects required to support the implicitly referenced object.
- Those references required to support each construct are detailed in the EXPRESS Manual.

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Example (USE)

```
SCHEMA ex206;
ENTITY first;
     a : second;
  END_ENTITY;
ENTITY second;
  END_ENTITY;
ENTITY third;
  END_ENTITY;
END_SCHEMA;
SCHEMA ex207;
USE FROM ex206
     (first);
END_SCHEMA;
```

- first is imported using USE
  - copied into the second schema
  - is independently instantiable
- second is implicitly referenced
  - copied into the second schema
  - is not independently instantiable
- third is not interfaced, explicitly or implicitly

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Entity types in a USE clause

- An entity specified in a USE clause may not be copied *exactly* as specified in the referenced schema.
- The supertype constraint may be changed due to subtype pruning via the interface specification
- By specifying ONLY those entities required in the interfacing schema, pruning of large graphs may be effected

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Example - subtype pruning

```
SCHEMA ex208;
ENTITY a
   SUPERTYPE OF (ONEOF
   (b,c,d));
   END_ENTITY;
ENTITY b; END_ENTITY;
ENTITY c; END_ENTITY;
ENTITY d; END_ENTITY;
END_SCHEMA;
```

- USE FROM ex208 (a);
  - imports a but not its subtypes
  - SUPERTYPE expression is deleted in the interfacing schema
- USE FROM ex208 (b,c);
  - imports a, b and c but not d
  - b and c (but not a) are independently instantiable
  - SUPERTYPE expression is "pruned":
  - SUPERTYPE OF (ONEOF (b,c));
- USE FROM ex208 (a,b,c)
  - What is the difference?

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Subtype pruning

- Subtype pruning is an important part of the STEP AIM development method
  - AIM "short form" - USE FROM interfaces, specializations
  - AIM "long form" - single schema resulting from resolution of all schema references
- Short form + Integrated Resources → Long Form
- Software tool developed by NIST
  - SHTOLO (SHort TO LOng form
  - Part of EXPRESS toolkit available via the Internet

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Reusable interpretations (templates)

- The same/similar requirement may occur many times within an AP
- When similar requirements map to similar AIM constructs, we can establish templates
- Today, this allows "cut-and-paste" with minor modifications from one mapping table to another
- In the future, a more formal mapping language may include parameterized templates
  - ⇨ *not* addressed by current draft of EXPRESS-X
- Ship AP projects have proposed a “macro” syntax
  - ⇨ development
  - ⇨ documentation

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Interpretation template: example

- Template to relate a product_definition to a name/value pair:

product_definition =
{=> **<product_definition subtype that is being mapped to>**}
characterized_product_definition =
characterized_definition <-
property_definition.definition
property_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation
representation.items[i] ->
representation_item =>
{representation_item.name = '**<name of the attribute>**'}
measure_representation_item

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Conclusions

- The Application Protocol development methodology has a very steep “learning curve”
  - EXPRESS usage
  - Integrated Resources
  - usage of Integrated Resources
  - Interpretation methods
  - documentation
- Most AP project teams go “in at the deep end”
  - first exposure is a full Interpretation Workshop
  - this training has been intended as a "gentler" introduction

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PDT Solutions